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Use of Belted Motor Drives in Power Transmission

Recognizing Special Conditions and Deciding What to Do—Proportioning Belt to Drive

By **ROBERT W. DRAKE**
Electrical and Mechanical Engineer, New York, N. Y.

This article is written for the man in the electrical or the millwrighting department who plans or uses motor belt drives, and for the many thousands of men operating plants or departments in which motors are used. The subject is purposely presented in a common sense way, in non-technical language.

The author is an authority on belt transmission. He was with the McCormick works of the International Harvester Co., in Chicago, for thirty years, in charge of power maintenance during most of this time.—The Editors.

ORDINARILY a motor belt drive that has been planned intelligently gives long and quite satisfactory service. The older men who have a background of many years of working with both motors and belts all know this.

The average motor-drive belt runs for a long time without any attention except that of keeping the leather from drying out and shortening the belt a time or two when it is new.

The operation of machinery by motors brings up a number of special conditions such as increasing the load, the speed or the output of the driven machine. When this happens some changes must be made in the belt drive to adapt the belt to the new condition. These changes are relatively simple and easy to understand if the operator knows what to do. However, if he has to make the changes and does not know what to do he may either find himself in trouble—or think himself in trouble—which amounts to the same thing.

It may be that a very small pulley drives to a large one on short centers with a violently fluctuating load exhibiting extreme peaks. It may be that, through no fault of the user, he has a motor operating with a motor pulley considerably smaller in diameter than the minimum diameter pulley specified by the manufacturer of the motor—which may develop bearing trouble. The belt speed may have to be increased. The motor may run too hot, the belt life may seem too short. All of these are special conditions to which the belt drive must be adapted.

Recognizing Special Conditions

It is the aim of this article to help the operator to recognize such special conditions, tell what to do and how to do it so that the belt drive will be free from trouble, should difficulties of any description arise. Trouble loses its terrors when we know the cure.

In what follows helpful suggestions are offered in the application of leather belts to motor drives only. All reference to alternative methods of driving is omitted, partly to avoid undue length and partly to avoid entering into any controversy as to the relative merits of leather belting and other means of connecting a motor to its driven load. There is a place for each type of drive, but as the great majority of all motor drives are flat leather belts, the present article is confined to a consideration of these alone.

A belt which will carry 10 h.p. is not necessarily suited to a 10-h.p. motor. The momentary overloads during starting and running determine the belt drive needed. Too often a belt drive is proportioned from consideration of average running conditions. Too often sight is lost of the fact that the belt must carry the peak loads as well as the running load. This accounts for a large proportion of all of the trouble encountered.

Fully one-half of the belted motor applications in industry require a heavier belt for starting than is required for satisfactory running. Practically all 3-phase a.c. motors which start on the line, and many d.c. motors, develop from 1/3 to ½ more belt pull at starting than when operating at full rated load. Wound rotor motors sometimes, and high slip linestart motors (high resistance rotor motors) always, develop twice normal full load belt pull at starting.

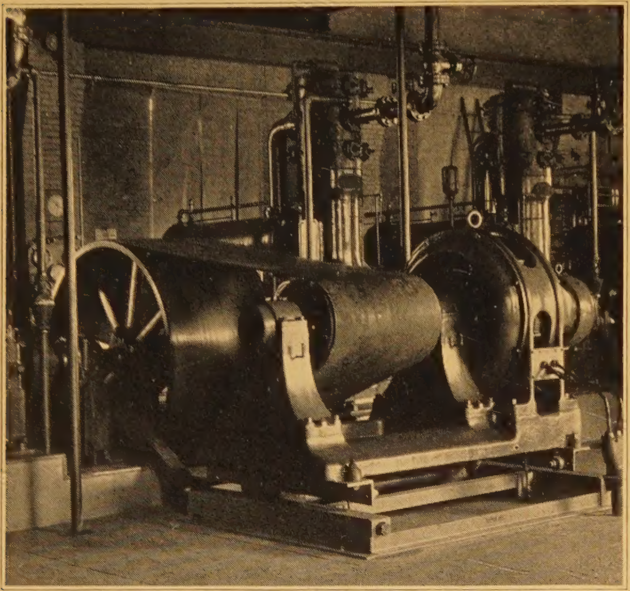
When a.c. linestart motors reach about ¾ full speed, or when compensator start motors are thrown over onto the line before they rise much above ¾ full speed, the belt pull rises to double full load for a time, a short time with an easy starting load, which comes up to speed quickly, a longer time for a slowly starting load.

The motor determines the belt pull during starting without reference to the requirements of the load. Any pull available in excess of that necessary to overcome starting resistance is used in hustling the load up to speed more quickly. It is a fact that a belt which will carry an excessive pull momentarily on an easy starting load, will frequently come off, if the same pull persists for several seconds, on a load which takes longer to start.

It is evident that the belt drive from a motor must in general be capable of carrying about twice the normal full load belt pull, at least for a short time during starting. In the case of many 60-cycle motors running at 1,800 r.p.m. and all high slip (high resistance rotor) motors, instead of twice full load pull, the belt must transmit 2½ times the full load pull.

We may overload a belt while starting a load, for we can tolerate considerable slip at starting. But after it is up to speed what is the maximum belt pull likely to be? This is a harder question to answer. It depends upon the type of driven load. We can, however, set an outside limit.

For loads having high momentary power peaks, such as a drill press when the drill breaks through, or on a small group of, let us say, three machines, which may occasionally work into step on such loads, when confronted with momentary demand for maximum power, most motors will deliver double the normal full load belt pull. Some high speed motors and high slip motors will deliver 2½ times the full load pull.



A 24 by 40-in. motor pulley driving a 72 by 40-in. pulley with a 38-in. triple leather belt, on 7 ft. 2 in. centers, at Dubuque city water works

To Have a Drive Carry More Power

If the capacity of a drive planned with the motor manufacturers' standard pulleys must be increased because of extreme load peaks, or for any other reason, what can be done to the drive? There are a number of expedients which will help in such cases. They are:

1. Putting on paper pulleys, if old ones are wood or metal;
2. Securing higher belt speed by means of larger diameter pulleys;
3. Using the pivoted motor base;
4. Using gravity idler drives;
5. Putting on a wider belt (provided the bearings will stand the extra belt pull necessary if a wider belt is to carry additional load).

Two or three of these expedients are all that are possible in any one case. Occasionally, when conditions are particularly unfavorable, two or three of these expedients must be employed in order to make a satisfactory drive.

Paper Pulleys

Where the smaller pulley of the drive is not paper, an increase of 25 per cent in drive capacity may be obtained by installing a paper pulley. Since all motor manufacturers furnish paper pulleys, they are generally used on the motor, but we sometimes lose sight of the fact that in speed-up drives the driven pulley is the smaller and should also be paper. Even on drives where the driven pulley is the larger, a worth-while improvement in capacity and a decrease in slip may be obtained by substituting a split paper driven pulley where the driven pulley is not more than 3 times as large as the driver.

Higher Belt Speed

The faster a belt is run up to 5,000-6,000 ft. per min., the more horsepower it will carry. Above 4,500 ft. per min. the gain in horsepower is not large.

Except for medium and large 1,750 r.p.m. motors and large 1,140 r.p.m. motors, manufacturers' standard pulleys give belt speeds decidedly below 4,500 ft. per min. In many cases it is possible to increase materially the horsepower capacity of an existing drive by increasing the belt speed without exceeding 4,500 ft. per min. The cost of two pulleys and a slight increase in belt length is moderate. Substantial increases in drive capacity are thus easily obtained without any increase in belt width, belt tension, or motor bearing loads.

On the smaller sizes of motors the belt speed can be increased more than is ever required, several hundred per cent in many cases. On medium sizes of motors operating at less than 1,800 r.p.m. the belt speed can be increased enough for ordinary "trouble" jobs.

Higher belt speeds may often be used where the drive carries the load satisfactorily, but the motor bearings heat dangerously. By substantially increasing the belt speed a narrower belt may be used, or the old belt may be run slack and the bearings greatly relieved.

Wherever the motor pulleys in service are smaller than the sizes tabulated below, higher belt speed should be considered first of all when relief is desired for an overloaded drive. For motors operating at 1,750 r.p.m. a 9¾-in. pulley corresponds to 4,500 ft. per min. Similarly for other motor speeds.

1,140 r.p.m. motor, 15-in. pulley, corresponds to 4,500 f.p.m.
850 r.p.m. motor, 20-in. pulley, corresponds to 4,500 f.p.m.
690 r.p.m. motor, 25-in. pulley, corresponds to 4,500 f.p.m.
570 r.p.m. motor 30-in. pulley, corresponds to 4,500 f.p.m.

In some cases the belt speed can not be increased. For instance, on a large 1,800-r.p.m. motor where the belt runs at 4,500 ft. per min. or more already. It may be found impossible to increase the driven pulley size because of interference with the ceiling, the floor, or with the frame of the driven machine.

Wider Belts

"Let's put on a wider belt." This is ordinarily the solution which first comes into one's mind when a belt drive operated at reasonable tension will not start the load, or when it fails to carry the extreme load fluctuations.

With motor belts this ordinarily is not the best solution for the problem.

Many shops endeavor to keep all motors of one horsepower capacity to one speed, so as to simplify the stocking of spare motors for use in case of motor breakdown. In fitting the shop standard speed motor to individually driven machines, cases arise where a wider belt than standard must be used. Perhaps the diameter of the driven pulley is fixed—a compressor, or a punch press flywheel—in which case the motor pulley must be somewhat smaller than the standard for that motor. Here more belt is needed because of lower belt speed.

It is worth while to say at this point, that if a motor pulley can be used that is not smaller than the motor manufacturers' standard diameter, by means of any reasonable expedient, it is the thing to do. The great majority of all troubles from motor drives result from using motor pulleys smaller than the standard.

With a smaller pulley, belt life is shortened. By using special, extra-flexible belting this can be avoided, at least in part, if the pulley is not too small. If the pulley diameter is to be decreased the belt must be wider, and in about the same proportion. As this is ordinarily expressed, the product of the pulley diameter and the face width should be kept the same as for the standard motor pulley. If this can not be done, then a pivoted motor base or gravity idler is generally advisable.

With a wider belt the load on the motor bearing will be greater than normal, bearing life will be shorter, and bearing operating temperature will be higher than normal.

There is ordinarily some allowance in the design of motor bearings for over-tightening belts, or for some slight increase in belt width. Such allowance is small in large high-speed motors, and is larger in moderate or slow-speed motors, and in small motors.

All motor manufacturers will furnish tables of data sheets showing the widest belt and the corresponding smallest pulley which any given frame, operated at any given speed, will stand without dangerously overloading the bearings. It is worth while for the plant engineer to provide himself with these data covering the lines of modern and obsolete motors which he is using.

In the absence of such data for a particular frame in question, a few general suggestions may be helpful. With the exception of motors built more than 20 or 25 years ago, and of motors built by two manufacturers whose product was always characterized by particularly rugged bearings, very few 1,750-r.p.m. sleeve bearing motors above 25 h.p. will stand any increase in belt width at all. This is likewise true of 1,140-r.p.m. motors of 50 h.p. and above.

Almost all 20 and 25-h.p., 1,750-r.p.m. motors, 30, 35, and 40-h.p., 1,140-r.p.m. motors, and 40 to 100-h.p., 850-r.p.m. motors, will stand at least 20 per cent increase in belt width, and some will stand 30 per cent or more. Smaller motors, say up to 10 h.p., will generally stand belts 30 per cent wider than standard, many will stand 40 per cent, some 50 per cent, the latter particularly in sizes of 5 h.p. and below.

There are exceptions to the above statements. A shrewd guess may be made at the exceptions, in the case of sleeve bearing motors, from the bearing temperatures of the some motors with tight belts of standard width. If the bearings run very hot, wider belts are not to be thought of. If hot, only 10 per cent wider, or 20 per cent if a pivoted motor base or gravity idler is also installed to reduce the chance of melting out a bearing by over-tightening the belt.

Roller Bearings

In the case of motors with ball bearings one expedient is available which frequently saves the day in such special applications, at least in the medium and smaller sizes of motors. There are, on the market, three makes of roller bearings, interchangeable in dimensions with standard ball bearings, which, within their speed limitations, will carry about twice as much load as standard ball bearings of the same dimensions. These bearings will carry no thrust loads.

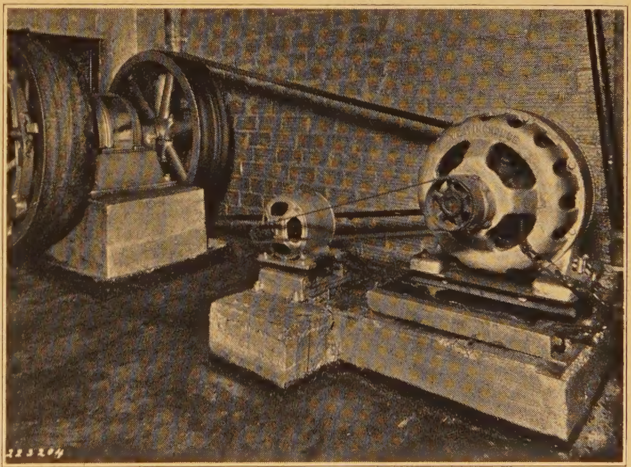
Where the speeds are not too high relative to the shaft diameter, that is, in medium and small sizes of motors, any reasonable increase in belt width is permissible with these roller bearings in the pulley end bearing and deep groove ball bearings in the front end to take the thrust. This permits belts 50 per cent wider than standard in almost all cases of 15 h.p. or below, and belts almost double standard width in small motors, particularly with the use of a pivoted motor base or gravity idler.

Pivoted Motor Base and Gravity Idler

These two types of drive are particularly useful when motor drives must be installed on very short centers. In fact, if with the short centers is combined a considerable difference in pulley size, some such special drive is almost a necessity.

In some respects the performance of these drives is similar. Let us discuss them together in so far as they are similar. Then we can bring out their points of difference by contrast.

A belt does all its work on the tight side, but there must always be a considerable pull on the slack side also to make the belt grip the pulley and prevent slippage.



A 60 by 13-in. fly wheel driving a 12 by 13-in. generator pulley with a 12-in. double leather belt, on 11 ft. 3 in. centers

With an ordinary belt drive, as the load comes on, the tight side stretches and passes extra length around into the slack side. Finally, as the load increases the slack side becomes so loose that the belt slips excessively. This is the extreme overload limit for the drive. To keep the capacity for occasional overload high, it is necessary to operate both slack side and tight side much tighter at normal loads than is necessary to carry normal loads.

Under heavy tensions belts stretch. It is usual to tighten the belt up more than necessary so that retightening for stretch will not be needed for some time. Both the pivoted motor base and the gravity idler drive greatly reduce, in most cases, the pulls on both the tight and the slack side of the belt at all loads except extreme overloads.

Even at extreme overloads they afford considerable relief, for they make it unnecessary to strain up the drive tighter than is needed for operating requirements in order to allow for subsequent stretch. The motion of the pivoted base or the gravity idler takes up the stretch.

Now, ordinary belt drives on motors operate at an average motor load not much exceeding the motor rating, but the belt tensions must be sufficient to enable the belt to carry about double the corresponding pulls momentarily during starting, and for short periods during operation.

In extreme cases with certain types of high speed motors, the belt must carry three times the normal pull momentarily, a small part of this being power delivered by the motor rotor as a flywheel in addition to the power delivered from the electrical operation of the motor.

A gravity idler or a pivoted motor base properly adjusted may carry heavier intermittent loads than an ordinary drive without overheating motor bearings, for the load on the motor bearings will be decreased during periods of light load and normal load.

During swings of abnormal load the bearing pressures will approach those of an ordinary open drive, but such periods do not last long enough to overheat the bearings. If they did the motor would burn up. Similarly, belts last longer if they are strained to carry extreme loads only during occasional swings of overload, and do not run so tight the remainder of the time.

Need Proper Adjustment

On such a drive, properly adjusted, it is safe to use a belt slightly wider than could be used on the same motor with an ordinary drive. This is a "life-saver" when pulleys smaller than standard are necessary on fairly high-speed motors. Note the words "properly adjusted" in the above sentence. Some manufacturers of gravity idler drives send out a liberal supply of weights with the drive and leave it to the customer to determine the number of weights to be used and their position. This would be fatal in a case where the motor bearings ran very hot, unless the customer promptly determined, on starting the job, the minimum weight required to carry the heaviest load fluctuations, and used no more.

As to the relative merits of the pivoted motor base drive and the gravity idler drive, which is the best? That depends upon circumstances. Like man and woman, they do most things in a more or less similar manner, but they are decidedly different in certain respects.

The pivoted base drive is ordinarily supplied with a high capacity oak tan belt. For comparison let us consider the performance of the idler drive when operated with a similar belt.

Some Points of Difference

The idler drive will carry somewhat more load with the same belt stress, motor bearing load, and motor bearing heating, because with the idler drive the belt is ordinarily in contact with decidedly more than half the motor pulley surface, while with the pivoted base drive the opposite is the case.

Where the driven pulley is four times as large as the motor pulley and the center distance is short, or where the pulley ratio is six with a longer center distance, the gravity idler drive will carry decidedly more load than the pivoted motor base drive, and it is the drive to use if extreme capacity is the one determining factor. Where the pulleys are more nearly the same size the idler drive shows less advantage in extreme capacity.

Disadvantages of Reverse Bend

Where the pulley ratio is within reason and it is not absolutely necessary to obtain the extreme limit of capacity from a given width of belt, the pivoted motor base drive has decided advantages. The gravity idler drive produces a severe reverse bend in the belt which greatly reduces belt life. It is a much more severe treatment for a double belt to be reverse-bent around a 6-in. or 8-in. roller as it leaves a 12-in. driving pulley, than to be run on a 6-in. or 8-in. driving pulley without reverse bending.

The idler drive has the further disadvantage that there is a considerable change in slack side tension with moderate belt stretch, 30 to 50 per cent change within the usual operating range of roller position on short center drives. Since the exact roller position is a matter for the judgment of the operator and frequency of adjustments, some 20 to 30 per cent allowance must be made in determining the idler weighting for a given peak capacity.

Unlike the gravity idler, the pivoted base adds no complications, no additional devices, nothing more to oil or to throw oil or grease, nothing more to wear out.

The belt creep and slip within the capacity of the drive is, for both the pivoted motor base drive and the gravity idler drive, so low as to be practically negligible, being normally less than 1 per cent.

The efficiency of the gravity idler drive is slightly less than for the pivoted base drive, for there is some roller friction and roller windage, and a slightly longer belt is required, thus increasing belt windage losses.

Getting Rid of "Trouble"

If the above suggestions are followed such a thing as "trouble" with a flat leather motor drive belt should seldom happen. Leather belt power transmission, when properly used, is the standard means of connecting the motor to its work. It combines long life, low maintenance cost and dependability with a sustained efficiency at average operating loads decidedly higher than those of most of the other available means of connecting a motor to its load.

Oklahoma State Cement Plant Proposed as "Club"

Establishment of a cement plant at a proposed sub-penitentiary in Atoka County, Oklahoma, would serve as a club to keep down the price of cement and prevent combination bidding, W. D. Hughes, chairman of the Oklahoma state board of affairs, stated recently.

"If this sub-prison is established, a cement plant could be built there. There is limestone rock on the land of the proper grade for making cement," Hughes said.

"The state might never have to use the plant, but at least it would have a club with which to force down the price of cement."

EDITORIAL

Prices and Sentiment Move Up

FAVORABLE news of major importance developed rapidly within the cement industry during the month of July.

Price advances reported from several sections in recent months were further consolidated by an advance of 40 cents per barrel in the middle west during the month just closed. One of the immediate results was a marked advance in the quoted prices of cement shares on the New York Stock Exchange. While it can not be said that the price of cement has become stabilized, a big step has been taken in that direction, and sentiment within the industry has responded accordingly.

July has also seen the return of four or five cement mills to their former membership in the Portland Cement Association, and the consequent return to duty of several association field engineers.

On the first day of July things looked no more encouraging for the cement industry than they did three months ago. The close of the month finds sentiment greatly improved and the outlook far more hopeful than it has been in many months.

What the Promoters Are Saying

BECAUSE of the large excess capacity in the cement industry and the greatly reduced shipments in 1931 and thus far in 1932, owners and officials of portland cement manufacturing plants in the United States will be interested to know that the promoters of a proposed new cement plant in the Lehigh Valley district of Pennsylvania, who are offering stock in the venture to the investing public, are predicting an annual production of 200 million barrels by 1935. The prediction is taken from a news item in the New York American, though the date of publication is omitted.

An equally surprising statement in the prospectus issued by the promoters appears under the subheading "Cement Shipments Gain." The paragraph under this heading is an Associated Press dispatch quoting the president of a cement company to the effect that the shipments of his company were 25 per cent greater in October, 1931, than in October, 1930. No mention is made of the fact that figures published by the U. S. Bureau of Mines place total cement shipments in the United States in October, 1931, at 20.8 per cent below October, 1930.

Another interesting statement in the prospectus carries the subhead, "An Opportunity to Participate in One of America's Largest and Most Profitable Industries." The reference to profit in the cement industry will cause many a cement plant executive to cry in his coffee.

Still another statement declares that "the investor seldom has an opportunity of acquiring cement stock. Because of the profitable nature of this class of security it is usually closely held by the original investors and any blocks for sale are quickly taken up. It is only when a new company is being organized that the public as a rule has been able to obtain a share in this highly profitable field of investment." This assertion is of particular interest in view of the fact that shares of more than 30 cement companies may now be bought on various stock exchanges, at prices far below their true book values.

It is fortunate that the cement industry knows how to bring the essential facts concerning this crippled and overbuilt industry to the attention of investors.

Books, Sermons, Mouse-Traps and Cement

SCHOOL children are told that "If a man writes a better book, or preaches a better sermon, or makes a better mouse-trap, than his neighbor, even though he builds his house in the woods, the world will make a beaten path to his door."

Bright school children learn to know better after they grow up, but some school children never do learn that they were only being hornswoggled. Unhappily, some of the latter group eventually get into the business of manufacturing cement, or manufacturing equipment for making cement.

In either case their product is likely to be of high quality, for they have learned the adage well; and the part that deals with quality is commercially sound. Their mistake lies in believing the rest of it, because the buying side of the commercial world no longer considers it necessary to make beaten paths through the woods to hunt out obscure manufacturers who make a good product but don't advertise. Buyers are more likely to order products or equipment which have been thrust most frequently upon their attention.

We are not so sure about books and sermons; but so far as mouse-traps and cement and cement-making equipment are concerned, the manufacturer's job is only half done when the product is ready to be shipped or delivered. The other half of the job is that of selling the product—through the medium of judicious advertising.

Hydration of Aluminous Cement

Decomposition of Calcium Silicate Is First Reaction—Later Formation of Hydrate of Dicalcium Aluminate Is Chief Reaction in Hardening Process

By K. KOYANAGI
Chichibu Cement Co., Ltd., Chichibu, Saitama-ken, Japan

ALUMINOUS cement is the youngest member among the hydraulic binding materials, and its appearance compelled us to become acquainted with a new sort of cement.

The first to investigate the hydration of aluminous cement microscopically was Biehl,[1] in 1926. He found in the hydration preparations of the German aluminous cement known as "Alca," some fine needles, hexagonal leaflets and gel drops. He gave the following solution of the composition of these new formations: The fine needles and hexagonal leaflets are hydrates of calcium aluminate, and gel drops are aluminum hydroxide. He gives the part of setting to the formation of calcium aluminates, and the part of proper hardening to the aluminum hydroxide gel.

Biehl[2] also allowed solutions of various salts to act on the aluminous cement, and observed the hydration products under the microscope.

Le Chatelier and Duhameax[3] announced that the cements containing less than 2CaO to $1Al_2O_3$ form the hydrate $2CaO.Al_2O_3.7H_2O$ on hydration, and cements containing much silicic acid always have an excess of lime hydrate after hydration and form the hydrate $4CaO.Al_2O_3.12H_2O$. They propose the following reaction for the hydration of aluminous cement:

$$2(5CaO.Al_2O_3) + 38H_2O = 5(2CaO.Al_2O_3.7H_2O) + Al_2O_3.3H_2O$$

The author[4] investigated in 1930 the hydration of French "ciment fondu." He obtained, by separating the hydrate of calcium aluminate and aluminium hydroxide in the hydration product, the following reaction:

$$2(CaO.Al_2O_3) + 11H_2O = 2CaO.Al_2O_3.8H_2O + Al_2O_3.3H_2O$$

As at that time the principal object of the research was not the investigation of the ordinary hydration process, but the prevention of flash set when mixing the aluminous cement with portland cement, the data obtained on hydration were scanty and unsatisfactory.

In the present paper, the action of water on the aluminous cement is first studied exhaustively, and then the hydration products formed are investigated chemically and microscopically, in a far more complete way than before.

The French "ciment fondu" of the following chemical composition was used:

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3
8.80%	39.64%	8.84%	42.30%	0.56%	0.09%

THE ACTION OF WATER ON ALUMINOUS CEMENT

I—The Solubility of Aluminous Cement in Water

The sample of cement, which was so finely ground as to pass the sieve of 10,000 meshes per sq. cm. completely, was shaken with water of the amount of 25, 50, 75 and 100 times the weight of the cement, for various lengths of time, and filtered. The quantity of Al_2O_3 and CaO dissolved in 100 cc. of clear filtrate was determined by analysis. For the shaking operation a shaking apparatus illustrated in Figure 1 was used.

Figure 2 shows the solubility curves of Al_2O_3 and CaO. Figure 3 shows the molar ratio $\frac{CaO}{Al_2O_3}$ in the solution. In Figure 2 it can be seen that the relation between the Al_2O_3 curves in various additions of water is approximately the same as that of the corresponding CaO curves.

The quantity of Al_2O_3 and CaO in the solution increases up to certain points, where it reaches its maximum, and after passing these points it decreases appreciably. The decrease of Al_2O_3 is more marked than that of CaO.

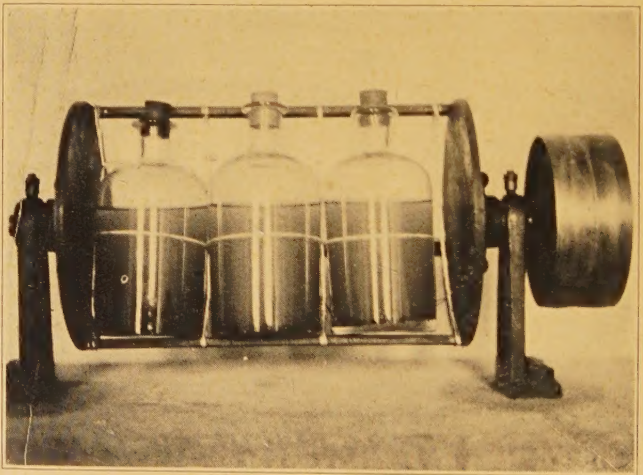


Figure 1

With the increasing addition of water, a longer time is required for solubility to attain its maximum.

The molar ratio $\frac{CaO}{Al_2O_3}$ attains its minimum just at the points where the solubility curves stand highest.

From these curves we can suppose that two reactions of different kinds occur when aluminous cement is treated with water. The first reaction occurs from the beginning to the highest points of solubility, causing a lowering of the lime-alumina ratio in the solution, while the second reaction begins at the maximum point of solubility, continues to the end of the experiments, and causes a rise of the lime-alumina ratio. The smaller the quantity of added water, the more rapidly both reactions go on.

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[1] *Zement*, 1927, p. 115 and 139.

[2] *Zement*, 1928, p. 842.

[3] *Chim. et Ind.*, 1929, No. 19, p. 417.

[4] K. Koyanagi, *Zement*, 1930, No. 37, p. 866.

II—The First Reaction in the Solution of Alumina Cement

A large quantity (80 g.) of cement was shaken with 100 times its weight of water[4a] for 18 hours (to the point where solubility is highest) and filtered. At filtration the author made a quite remarkable observation; a considerable quantity of white globular crystals of the size of 1/10—1 mm. diameter, was found mixing in the cement residue. This crystal could be separated without difficulty from the dark colored cement residue, by sifting with the sieve of 10,000 meshes per sq. cm., using absolute alcohol as the washing medium. The globular crystal remained on the sieve, while the cement residue was so fine that it passed the sieve completely. The crystal was washed thoroughly with ether and dried to constant weight in the vacuum desiccator, and used as a sample for analysis. By examination under the microscope it was confirmed that the sample for analysis was completely free from the dark colored cement residue. Figure 4 shows the microscopic photograph of the globular crystals.

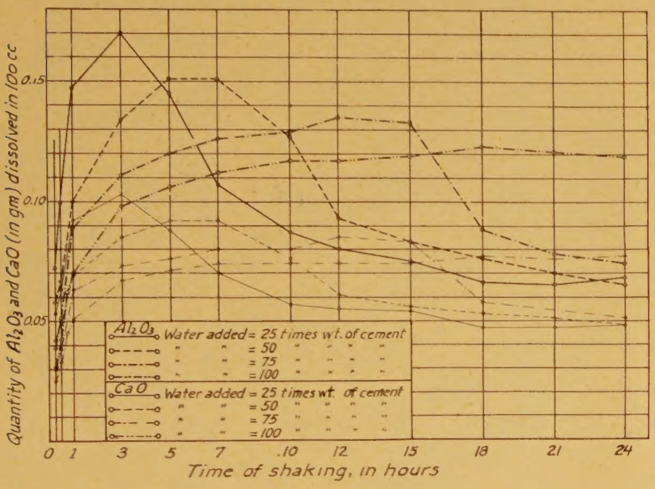

Figure 2

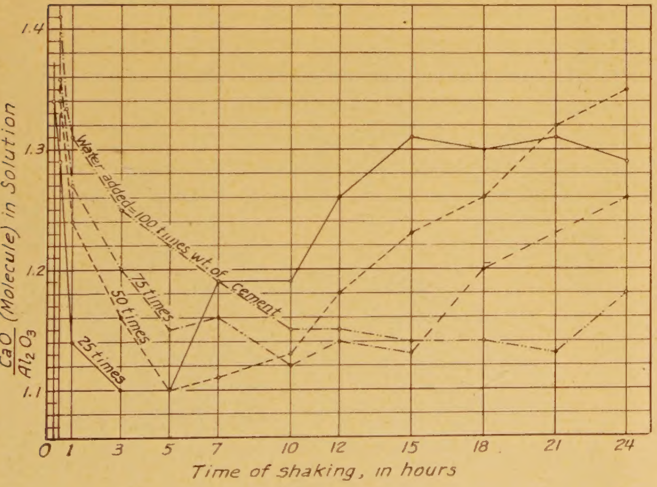

Figure 3

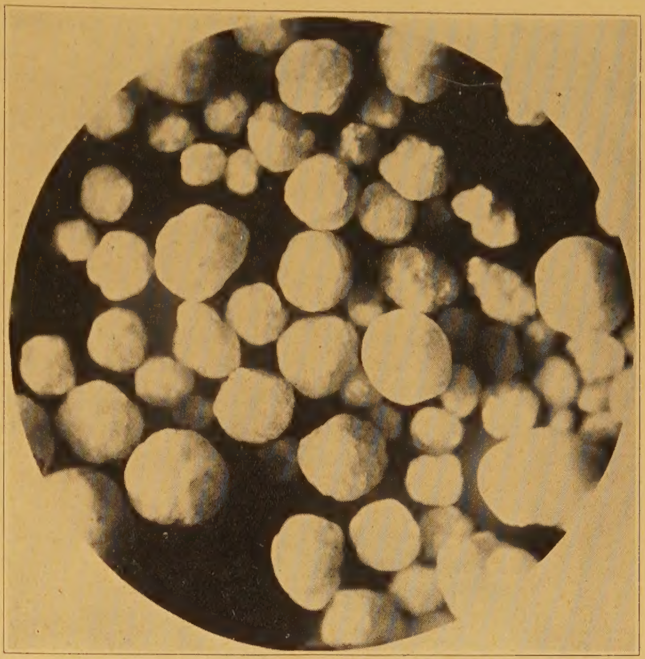

Figure 4

The crystal was soluble in dilute hydrochloric acid (1/10 N) and left no residue. Table 1 shows the results of the analysis.

TABLE 1

Sample	Percentage			Molecule		
No.	Ign. loss	Al_2O_3	CaO	Al_2O_3	CaO	Cryst. H_2O
1	38.68	28.80	31.50	1	1.99	7.60
2	37.82	29.25	32.45	1	2.02	7.32
3	38.23	28.83	32.10	1	2.02	7.50
4	38.24	28.85	32.10	1	2.02	7.50
5	39.18	28.46	31.35	1	2.00	7.79
Avge.				1	2.01	7.54

It shows that the globular crystal consists of the hydrate $2CaO.Al_2O_3.7.5H_2O$.

As it was determined by microscopic examination that no aluminium hydroxide gel is formed in the cement residue within 18 hours of shaking, so the lowering of the lime-alumina ratio in the first half of the solubility curves (see Figure 3) is to be explained from the formation of a small quantity of $Ca(OH)_2$, by the hydration of calcium silicate in aluminous cement, and this lime combines with monocalcium aluminate and forms the hydrate $2CaO.Al_2O_3.7.5H_2O$ in accordance with the following reaction: $CaO.Al_2O_3 + Ca(OH)_2 + 6.5H_2O = 2CaO.Al_2O_3.7.5H_2O$.

This reaction goes on very vigorously if there is much $Ca(OH)_2$ in the solution, but as "ciment fondu" contains only a small quantity of silica, and the quantity of $Ca(OH)_2$ formed on hydration of calcium silicate is not great, the above-mentioned reaction occurs comparatively slowly, on account of the small concentration of lime in the solution. The calcium hydroxide in the solution is consumed in the meantime, and the reaction ceases.

[4a] Water amounting to 100 times the weight of cement was chosen, because with smaller quantities of water the reaction goes on too quickly, making it impossible to observe the reaction accurately.

The quick setting quality of aluminous cement with high silica content, and also the flash set which occurs on mixing aluminous cement and portland cement, are considered to be partly caused by this reaction. With regard to the action of lime upon aluminous cement on hydration, the writer is conducting at present an exhaustive investigation, which will be reported later in the *Cement Mill Edition of* CONCRETE.

III—The Crystal Form and Optical Properties of $2CaO.Al_2O_3.7.5H_2O$

Some thin slices were made out of comparatively big ones of the globular crystal. On examining the slices under the microscope, it was found that numerous crystals grow around a nucleus, radiating outward. (Figure 5.) The thin slices of about 0.03 mm. thickness showed, when observed in parallel polarized light, an interference color of grey white, first order, which indicates that the double refraction of the crystal is not so strong.

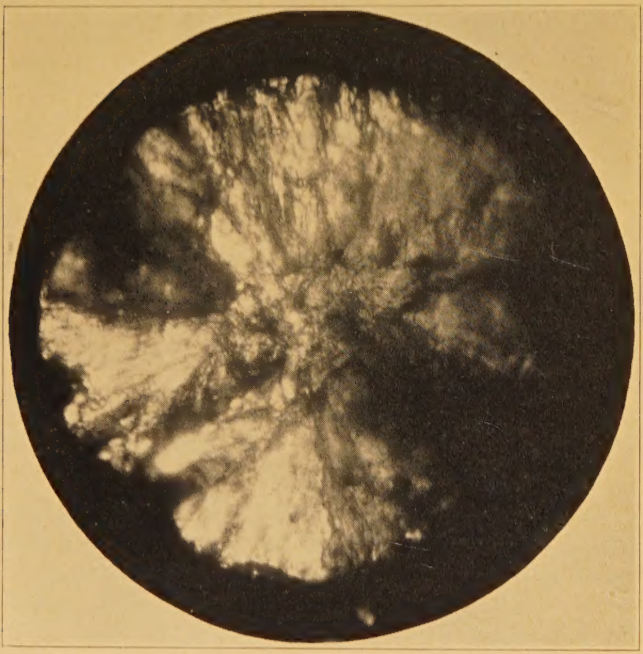

Figure 5

The crystal form of dicalcium hydroaluminate is made clearer by the following experiments: Aluminous cement was shaken with 100 times its weight of water for a shorter time than before, or a total of 8 hours, and filtered. The clear filtrate was poured into glass bottles and shut off from the air. After some time there appeared a great number of fine crystals, which were at first spherical in form (Figure 6). Many crystal leaflets appeared on them afterward (Figure 7).

The crystals are, in their full growth, hexagonal in form, and include in their center a nucleus and needle crystals growing around this nucleus (Figure 8).

The analysis of this hexagonal crystal is given below:

Percentage			Molecule		
Ig. loss	Al_2O_3	CaO	Al_2O_3	CaO	Cryst. H_2O
38.12	28.80	31.39	1.00	1.99	7.50

The crystal is identical with the previously mentioned globular crystal, and consists of dicalcium hydroaluminate $2CaO.Al_2O_3.7.5H_2O$. The optical properties of this crystal were examined. It is optically negative, uniaxial, shows parallel extinction, refractive indices: $\omega D = 1.520 \pm 0.002$, $\epsilon D = 1.512 \pm 0.002$, double refraction 0.008.

The formation of globular crystals in the above-mentioned dissolving process is to be explained from the fact that the crystal of $2CaO.Al_2O_3.7.5H_2O$, which should otherwise possess a hexagonal form, was rubbed by the rotating motion of the solution in the shaking apparatus, lost all its edges and thus attained the globular form.

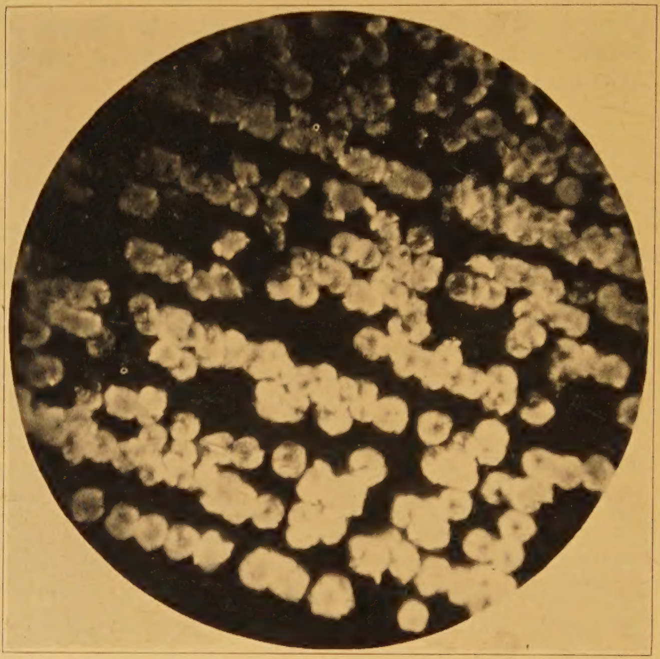

Figure 6

The optical data of $2CaO.Al_2O_3.7.5H_2O$ are compared

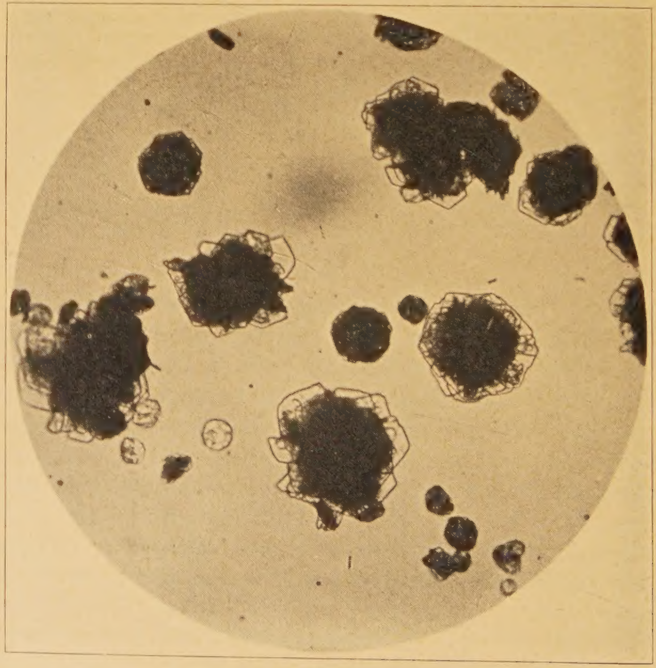

Figure 7

TABLE 2

Formula	Optical characters	Refractive indices ωD	Refractive indices εD	Authors	Remarks
$4CaO.Al_2O_3.12H_2O$	Uniaxial negative	1.532	1.505	L. S. Wells	
$3CaO.Al_2O_3.12H_2O$	Uniaxial negative	1.527	1.505	Thorvaldson	Hydration product of artificial melts of calcium aluminate
$3CaO.Al_2O_3.10.5H_2O$	Uniaxial negative	1.530	1.510	Thorvaldson	
$3CaO.Al_2O_3.8H_2O$	Uniaxial negative	1.538	1.520	Thorvaldson	
$3CaO.Al_2O_3.7H_2O$	Uniaxial negative	1.538	1.523	Pulfrich & Link	
$3CaO.Al_2O_3.5H_2O$	Uniaxial negative	1.539	1.524	K. Koyanagi[5]	A hydration product of portland cement clinker
$2CaO.Al_2O_3.7H_2O$	Uniaxial negative	1.535	1.515	L. S. Wells	Hydration product of monocalcium aluminate
$2CaO.Al_2O_3.7.5H_2O$	Uniaxial negative	1.520	1.512	K. Koyanagi	A hydration product of aluminous cement

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[5] *Zement*, 1931, No. 45, p. 968.

in Table 2 with the investigations of hydrate of calcium aluminate hitherto made.

IV—The Second Reaction Occurring in the Solution

The clear filtrate in Section III (the cement was shaken with 100 times its weight of water for 18 hours) was sealed airtight in glass bottles, and let stand for a period of 4 months, and the reaction occurring in the solution was observed carefully.

After some 5 days, a quite weak formation of fine crystals was observed to have begun, and 1½ days later the solution became a little turbid. The turbidity of the solution increased more and more until the eleventh day, when the solution became nearly clear again. From time to time a sample of the solution was taken from one of the glass bottles and filtered, and 100 cc. of the clear filtrate was analyzed for Al_2O_3 and CaO.

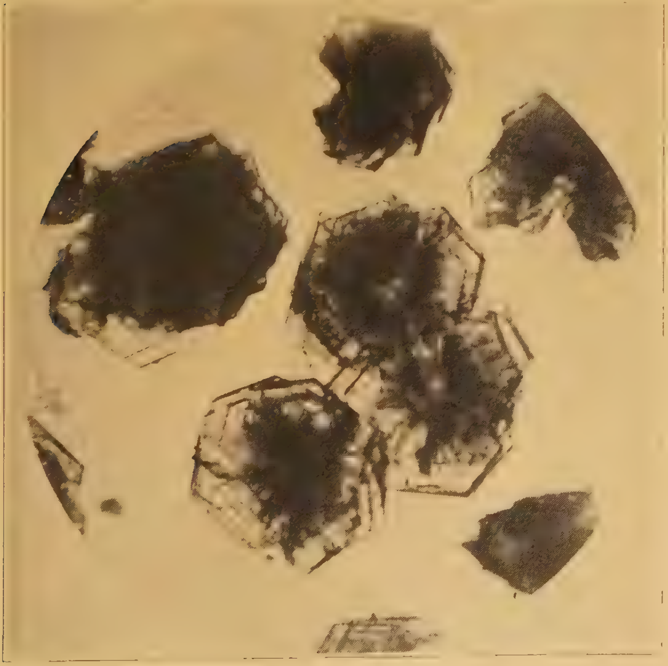

Figure 8

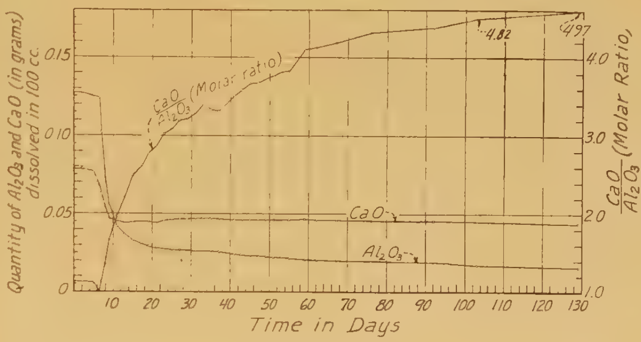

Figure 9

Table 3 and Figure 9 show the quantity of Al_2O_3 and CaO, in grams, dissolved in 100 cc., and the molar ratio $\frac{CaO}{Al_2O_3}$ in the solution. The quantity of alumina and lime begins a sudden and rapid decrease at the elapsed time

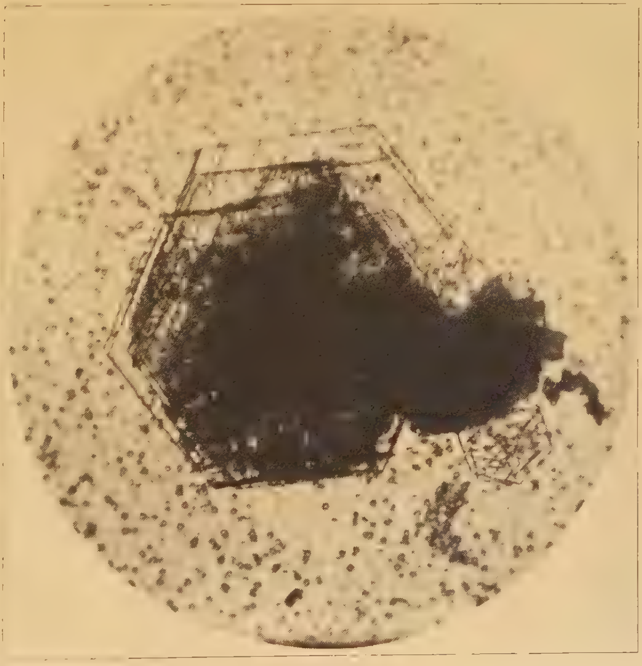

Figure 10

of 6½ days, and on the same day the lime-alumina ratio attains its minimum (i. e., $\frac{CaO}{Al_2O_3} = 1.00$). The decrease of CaO in the solution ceases completely on the eleventh day, when the lime-alumina ratio stands at about 2. The quantity of CaO remains nearly constant from the eleventh day to the end of the experiment, while the quantity of Al_2O_3 continues to decrease from the beginning to the end.

From this experiment it can be seen clearly that *the precipitation of calcium aluminate ceases almost completely on the eleventh day, and thereafter only aluminium hydroxide comes out of solution.*

TABLE 3

No.	Time of storage in days	Quantity dissolved in 100 cc. of solution (in grams) Al_2O_3	CaO	Molar ratio $\frac{CaO}{Al_2O_3}$
1	0	0.1270	0.0786	1.13
2	1	0.1262	0.0785	1.13
3	2	0.1272	0.0786	1.13
4	3	0.1264	0.0786	1.13
5	5	0.1250	0.0770	1.12
6	6½	0.1240	0.0680	1.00
7	7	0.1019	0.0632	1.13
8	8	0.0724	0.0540	1.36
9	9	0.0554	0.0472	1.67
10	11	0.0422	0.0457	1.97
11	13	0.0364	0.0442	2.21
12	15	0.0326	0.0445	2.48
13	17	0.0312	0.0448	2.61
14	19	0.0290	0.0441	2.77
15	21	0.0276	0.0440	2.90
16	23	0.0274	0.0455	3.02
17	25	0.0272	0.0460	3.08
18	27	0.0265	0.0465	3.19
19	29	0.0263	0.0463	3.21
20	31	0.0261	0.0470	3.28
21	33	0.0252	0.0469	3.39
22	35	0.0257	0.0470	3.33
23	37	0.0256	0.0466	3.31
24	41	0.0240	0.0461	3.50
25	43	0.0234	0.0460	3.58
26	45	0.0229	0.0460	3.66
27	47	0.0229	0.0464	3.67
28	49	0.0224	0.0458	3.72
29	51	0.0222	0.0459	3.76
30	53	0.0219	0.0458	3.81
31	55	0.0218	0.0458	3.82
32	59	0.0207	0.0465	4.09
33	62	0.0204	0.0462	4.12
34	67	0.0200	0.0459	4.18
35	76	0.0193	0.0457	4.31
36	92	0.0189	0.0455	4.38
37	103	0.0170	0.0450	4.82
38	129	0.0161	0.0440	4.97

On the eleventh day the contents of some of the glass bottles were filtered. The deposits clinging firmly on the glass wall were almost completely removed by scraping with a glass rod. The precipitate was washed first with absolute alcohol, then with ether, and dried in a vacuum desiccator to constant weight. It was determined by microscopic examination that the precipitate consists of a mixture of hexagonal crystals and a gelatinous substance (Figure 10).

The optical properties of the hexagonal crystals were examined and found to be quite the same as those of the crystal $2CaO.Al_2O_3.7.5H_2O$. The crystal must therefore be the same substance. The amorphous gel substance was determined by means of the dyeing method to be aluminium hydroxide.

V—The Separation of the Crystal and Gel Substance in the Precipitate

The author had experimented on the separation of the same substances in his earlier investigation.[6] The process chosen in this investigation was that the substance was ignited in a platinum crucible in an electric furnace, and then boiled with dilute hydrochloric acid. The calcium aluminate should be dissolved, while free alumina should remain insoluble. The exact composition of the hydration product could, however, not be obtained by this experiment, because the free alumina and calcium aluminate in the precipitate showed a strong tendency to combine with each other, during ignition, at comparatively low temperatures, as 800 to 1200 deg. C., forming another calcium aluminate of lower lime content than the original one. Besides, the alumina ignited at these temperatures is still more or less soluble in the dilute hydrochloric acid. Both factors lower the lime-alumina ratio in the soluble part of the precipitate.

From the failure of this earlier investigation the author learned that, in order to get the exact composition of the hydration product, it is unconditionally necessary to know the quantity of the free alumina which combines with calcium aluminate during ignition and becomes soluble in dilute hydrochloric acid.

For this purpose the pure hydrate of dicalcium aluminate described in the previous section as having been isolated, was mixed intimately with the freshly precipitated aluminium hydroxide and was ground in an agate mortar. Then 0.5 gram of this mixture was ignited in a platinum crucible at 800 deg. C. for half an hour. The ignited substance was, after cooling, poured into a beaker with 150 cc. of dilute hydrochloric acid (1/10 N) and boiled for 5 minutes,[7] then filtered. The residue on the filter was washed thoroughly with warm water, ignited, and weighed as insoluble Al_2O_3.

The quantity of the free Al_2O_3 in the original mixture was calculated. The difference between these two quantities of Al_2O_3 is the quantity of Al_2O_3 which had combined with calcium aluminate during ignition and became soluble in dilute hydrochloric acid.

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[6] *Zement*, 1930, No. 37.

[7] It was determined by another experiment that 5 minutes boiling with 150 cc. 1/10N HCl is enough to dissolve the quantity of dicalcium aluminate contained in 0.5 gram of the original mixture.

TABLE 4

Experiment No.	Mixing proportion $2CaO.Al_2O_3.7.5H_2O$	Mixing proportion $Al_2O_3.3H_2O$	Free and insoluble Al_2O_3: Free Al_2O_3 (calculated)	Free and insoluble Al_2O_3: Insoluble Al_2O_3 after ignition (obtained)	$F = \frac{\text{Free } Al_2O_3 \text{ (calculated)}}{\text{Insol. } Al_2O_3 \text{ (obtained)}}$
1	46.61%	53.39% (a)	36.71%	25.00%	1.4684
2	46.61%	53.39% (b)	35.99%	24.18%	1.4883
3	46.61%	53.39% (c)	36.52%	25.04%	1.4584
Average	-----------	-----------	-----------	-----------	1.4717

By dividing the free Al_2O_3 added to the original mixture with insoluble Al_2O_3, the factor F was calculated, as follows:

$$F = \frac{\text{Free } Al_2O_3 \text{ calculated}}{\text{Insoluble } Al_2O_3 \text{ obtained}}$$

The analyses of the dicalcium aluminate and the aluminium hydroxide used as samples in the experiment were as follows:

	Hydrate of dicalcium aluminate $2CaO.Al_2O_3.7.5H_2O$	Aluminium hydroxide $Al_2O_3.3H_2O$ (a)	(b)	(c)
Al_2O_3	28.80%	68.76%	67.41%	68.39%
CaO	31.37%	-----------	-----------	-----------

The results of these experiments are given in Table 4.

Now the hydration product (mixture of hexagonal crystal and gel substance) was treated on just the same conditions as above. If the insoluble Al_2O_3 obtained here be multiplied by the factor F, then the Al_2O_3, which exists in the hydration product as free Al_2O_3, can be obtained, and if this free Al_2O_3 is subtracted from the total Al_2O_3, then the combined Al_2O_3 is obtained, and herewith the exact lime-alumina ratio of the calcium aluminate in the hydration product can be calculated. The results of the experiments are given in Table 5.

As was foreseen in the microscopic examination described in the preceding section, the hexagonal crystal formed in the hydration product consists of dicalcium hydroaluminate.

It is now necessary to refer once more to the results given in Table 3. The quantities of Al_2O_3 and CaO dissolved in 100 cc. of the solution on the sixth day and the eleventh day, and the precipitate which was given out of 100 cc. of the solution between the elapsed time of 6½ and 11 days, are as follows:

	Combined CaO	Combined Al_2O_3	Free Al_2O_3	Molecule Al_2O_3 Comb.	Molecule CaO Comb.	Molecule Al_2O_3 Free
6th day, dissolved in 100 cc. of solution	0.0680g	0.1240g	None	2	2	0
11th day, dissolved in 100 cc. of sol.	0.0457g	0.0422g	None			
	0.0680g	0.0625g	0.0615g	2	1	1
6½-11 days, precip. out of 100 cc. sol.	0.0223g	0.0203g	0.0615g			

We can see clearly from this that the following reaction occurred[8] in the interval between 6½ and 11 days:

$$2(CaO.Al_2O_3) + 10.5H_2O = 2CaO.Al_2O_3.7.5H_2O + Al_2O_3.3H_2O$$

This is the chief reaction occurring in the hydration of aluminous cement, and the hardening of the cement is mainly due to this reaction.

After the eleventh day no calcium aluminate is precipitated, and only aluminium hydroxide continues to deposit. The lime-alumina ratio goes higher and higher. In Figure 9 we can see that the curve for $\frac{CaO}{Al_2O_3}$ goes on very smoothly until about the twenty-third day, when it reaches 3.

The part of the curve from 6½ to 23 days can be expressed by the following parabolic formula:

$$D = 5.64 + 0.9386C^{2.603}$$

or $$\log(D - 5.64) = 0.02753 + 2.603 \log C$$

in which $$D = \text{time in days}$$

TABLE 5

Sample No.	Analysis: Total Al_2O_3	Analysis: Total CaO	Analysis: Insoluble Al_2O_3 (after ignition) (P)	Calculation: Free Al_2O_3 P × F	Calculation: Combined Al_2O_3 total Al_2O_3 — (P × F)	Calculation: Combined CaO	Calculation: $\frac{CaO}{Al_2O_3}$ (molar ratio) in Calcium aluminate
1	46.50%	13.26%	23.26%	34.24%	12.26%	13.26%	1.97
2	46.94	13.20	23.44	34.50	12.44	13.20	1.93
3	46.76	13.30	23.36	34.38	12.38	13.30	1.95
4	46.30	13.26	23.46	34.52	11.78	13.26	2.05
5	47.36	13.30	23.90	35.18	12.18	13.30	1.99
6	47.20	13.26	23.60	34.76	12.44	13.26	1.94
7	47.22	13.36	23.68	34.84	12.38	13.36	1.96
Average	-------	-------	-------	-------	-------	-------	1.97

$$C = \frac{CaO}{Al_2O_3} \text{ (molar ratio)}$$

The values of C calculated from this formula coincide very well with the actual values shown in Tables 6 and 3.

TABLE 6

Time in days	$\frac{CaO}{Al_2O_3}$ C	C (calculated)	Difference
6½	1.00	0.97	+0.03
7	1.13	1.15	—0.02
8	1.36	1.43	—0.07
9	1.67	1.63	+0.04
11	1.97	1.95	+0.02
13	2.21	2.21	0.00
15	2.48	2.42	+0.06
17	2.61	2.61	0.00
19	2.77	2.77	0.00
21	2.90	2.93	—0.03
23	3.02	3.07	—0.05

After the twenty-third day the curve for $\frac{CaO}{Al_2O_3}$ runs very irregularly, approaching close to the value of 5 by the beginning of the fourth month. From this it is very likely that the hydrate of dicalcium aluminate, which still remains in the solution in quite a small quantity on the eleventh day, gives up one more molecule Al_2O_3 and changes into tricalcium aluminate, as follows:

$$3(2CaO.Al_2O_3.7.5H_2O) + H_2O = 2(3CaO.Al_2O_3.10.5H_2O) + Al_2O_3.3H_2O$$

This tricalcium aluminate decomposes in the solution afterward, into free lime hydroxide and aluminium hydroxide, as follows:

$$3CaO.Al_2O_3.10.5H_2O = 3Ca(OH)_2 + Al_2O_3.3H_2O$$

These last two reactions do not occur so much in the hydration of aluminous cement, and exert practically no influence upon the hardening of the cement, because the solubility of $2CaO.Al_2O_3.7.5H_2O$ in water is quite small.

Summary

(1) In the hydration of the aluminous cement "ciment fondu," a small quantity of lime hydroxide is first formed by the decomposition of the calcium silicate contained in the cement, and this lime combines with monocalcium aluminate to form the hydrate $2CaO.Al_2O_3.7.5H_2O$ as follows:

$$CaO.Al_2O_3 + Ca(OH)_2 + 6.5H_2O = 2CaO.Al_2O_3.7.5H_2O$$

This reaction goes on very strongly, if there is enough lime in the solution. It occurs, however, in quite a small quantity and comparatively slowly in the hydration of ciment fondu, on account of the small concentration of lime hydroxide in the solution, because the cement contains only a small quantity of silica or calcium silicate.

(2) When all calcium hydroxide in the solution is consumed by the above reaction, then the second reaction begins. Monocalcium aluminate gives up a molecule of aluminium hydroxide and changes into the hydrate of dicalcium aluminate of the same chemical composition as above:

$$2(CaO.Al_2O_3) + 10.5H_2O = 2CaO.Al_2O_3.7.5H_2O + Al_2O_3.3H_2O$$

This is the chief reaction occurring in the hydration of aluminous cement, and the hardening of the cement is mainly due to this reaction.

(3) The dicalcium hydroaluminate, which remains in the solution in quite a small quantity, gives up one molecule $Al_2O_3.3H_2O$ and changes into the hydrate of tricalcium aluminate, as follows:

$$3(2CaO.Al_2O_3.7.5H_2O) + H_2O = 2(3CaO.Al_2O_3.10.5H_2O) + Al_2O_3.3H_2O$$

The tricalcium aluminate thus formed decomposes later into lime hydroxide and aluminium hydroxide, as follows:

$$3CaO.Al_2O_3.10.5H_2O = 3Ca(OH)_2 + Al_2O_3.3H_2O$$

These last two reactions are comparatively unimportant, and exert practically no influence upon the hardening of the aluminous cement, because the solubility of $2CaO.Al_2O_3.7.5H_2O$ in water is very small.

Middle West Cement Prices Jump 30 Cents

An advance averaging 30 cents a bbl. in the base as well as the retail price of cement went into effect in Chicago on July 19.

Paving, curbing and highway work was credited with absorbing cement in much better volume than thirty or sixty days ago and the outlook was reported encouraging.

The Missouri Portland Cement Co. on the following day announced that the price of cement had been increased 30 cents a bbl. to $1.15, against 85 cents previously.

List of Geological Publications Made Available

A list of publications on the geology of Illinois and its mineral resources is now available upon request, the Illinois State Geological Survey at Urbana has announced.

Included is a serial listing of the bulletins and maps, and a special subject, county, and author index.

PERSONALS

Stanley Owens, for the past two years safety engineer of the Portland Cement Association, is no longer with that organization due to curtailment in activities.

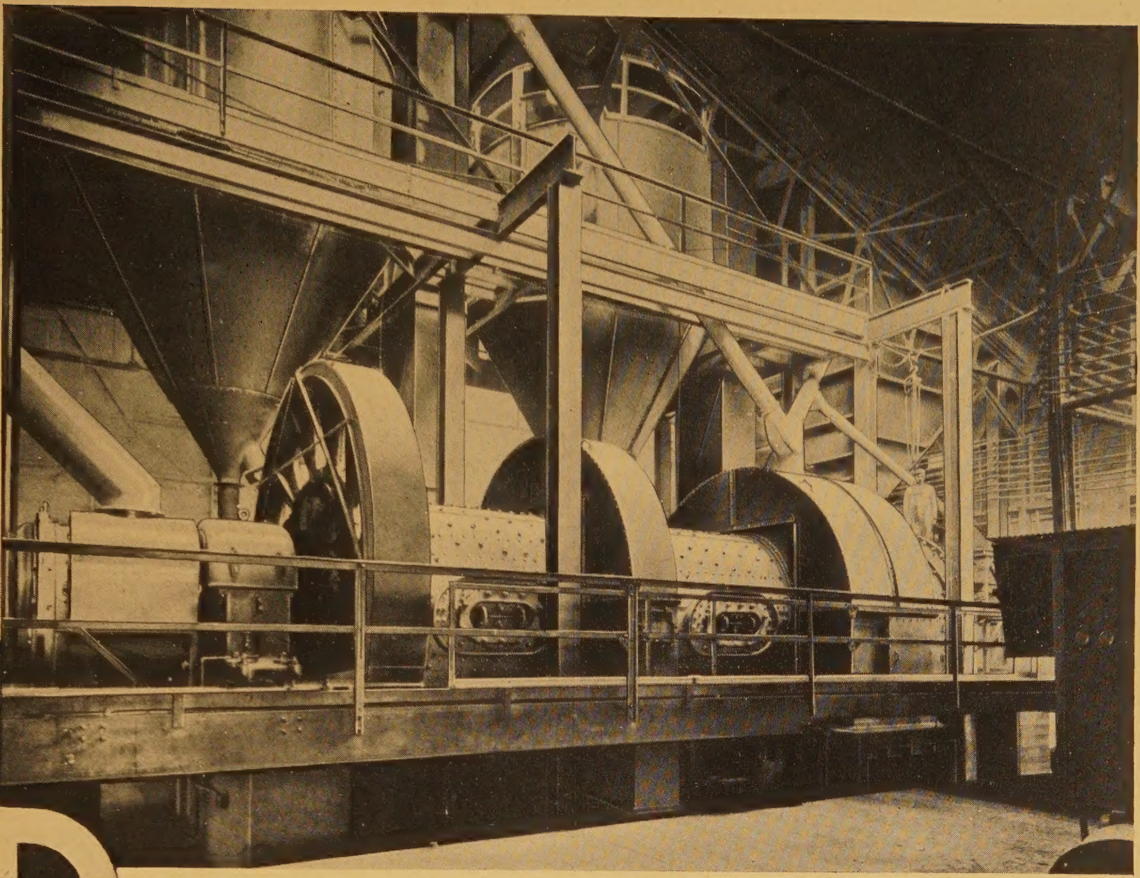
His work and training have been in the specialization of safety engineering, public utility and trade association work.

While with the association he acted in an advisory capacity to the safety directors of member companies, and inspected plants, conducted safety meetings, and arranged regional safety gatherings.

Walter A. Wecker, secretary and treasurer of Marquette Cement Mfg. Co., has been elected a vice-president of that organization. He will continue in the former position as well.

Dr. Max Polysius, president of the Polysius Corp., Dessau, Germany, and Bethlehem, Pa., passed away on June 18 after an illness of several months.

He had visited the United States on several occasions.



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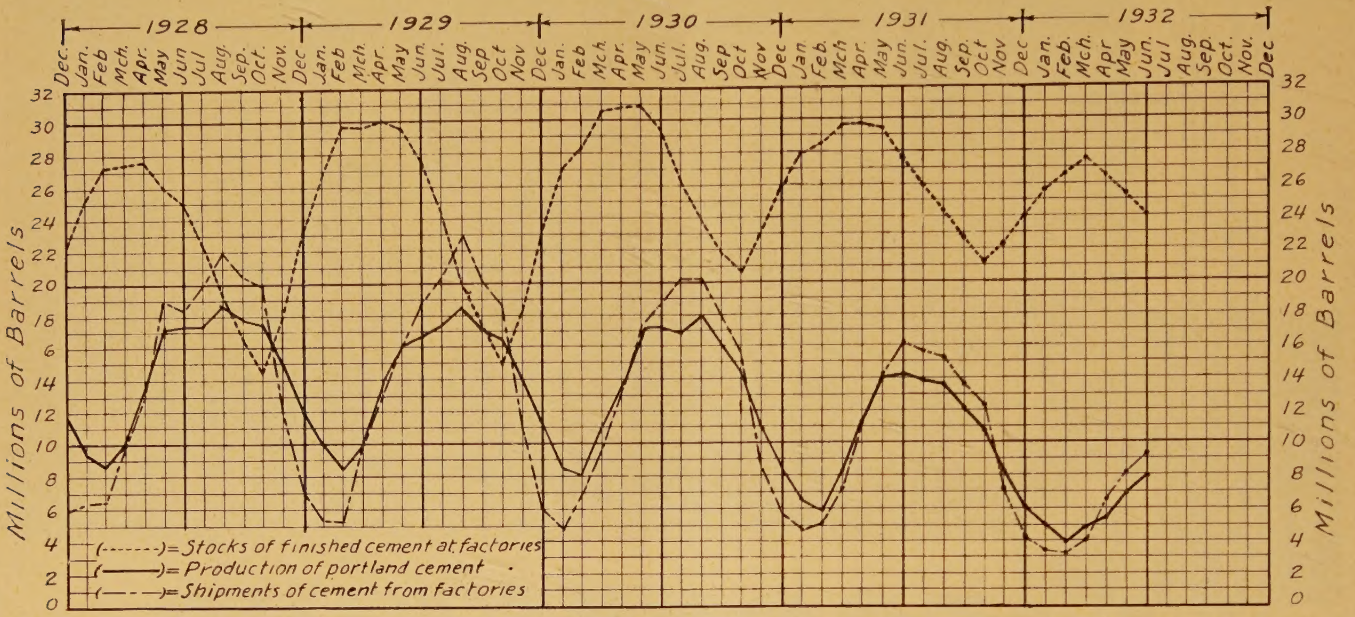
Cement Statistics for June

Relation of Production to Capacity

	The Month	Twelve Months
June, 1932	35.7	36.5
June, 1931	65.4	55.2
May, 1932	30.2	38.9
April, 1932	24.8	41.7
March, 1932	21.3	43.8

Production, Shipments and Stocks of Finished Portland Cement

	1931	1932
Production, June	14,118,000	7,921,000
Shipments, June	16,077,000	9,264,000
Stocks at end of month	27,602,000	24,051,000
Production for year to date	60,133,000	34,156,000
Shipments for year to date	58,419,000	34,304,000

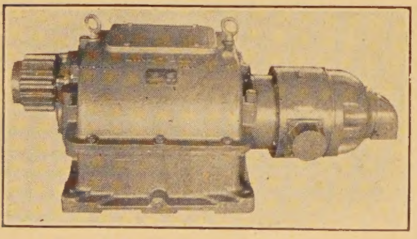


Mill Equipment

Motorized Speed Reducer Is New Link-Belt Product

A new motorized speed reducer has recently been added to the line of enclosed speed reducing units built by Link-Belt Co., Philadelphia.

The reducer illustrated is a triple reduction unit with a speed ratio of 312.2 to 1, being one of a lot of 32 made for driving sludge collectors at New York City's new sewage treatment plant on Ward Island. The motor shaft (which extends into the reducer housing) operates at 1165 r.p.m., and the low speed shaft at only 3.75 r.p.m.



The advantages of using a motor with extended shaft, and mounting it in this manner, are the increased efficiency and compactness, reducing the floor space required, and elimination of high-speed motor-shaft coupling, the Link-Belt Co. states.

Roller bearings and continuous-tooth herringbone gears are used. The gears run in oil, to provide automatic lubrication of the gears and bearings. The tabulated ratings will be for continuous duty, allowing for 100 per cent momentary overloads.

Industrial Literature

Dings Publications

The Dings Magnetic Separator Co., Milwaukee, has recently prepared a 16-page bulletin on the installation and use of magnetic clutches for special and general transmission applications. The bulletin describes three types of Dings magnetic clutches—single disk, multiple disk, and serrated disk.

A number of installation diagrams are reproduced and the method of calculating the required horsepower rating is discussed in detail. Extensive tables of performance data are also included.

An interesting treatise of the separation of such feebly-magnetic substances as iron oxide, garnet, hematite, slate and wolframite from non-magnetic substances is included in a new bulletin also published by the Dings company describing the new Dings Type IR Super-High Intensity magnetic separator.

Ingersoll-Rand Pumps

A folder prepared by the *Ingersoll-Rand Co.*, New York City, describes briefly its new line of merchandising Motorpumps.

They are available in sizes from ¼ to 25 h.p., handling from 5 to 800 gal. per minute.

The Motorpump is a complete pumping unit with built-in electric motor. Open-type, totally enclosed or explosion-proof units can be furnished.

Motor Characteristics Table

Engineers and plant executives may secure on request a table of motor characteristics from the *Triumph Electric Corp.*, Cincinnati, Ohio.

The table is convenient for determining correct types of motors for various applications and in checking performance of old installations for the purpose of reducing connected load and raising power and load factor.